THE SIZE OF A MOLECULE

Molecules are much too small to be observed directly. However, because some molecules will form layers that are one molecule thick on water, it is possible to determine the order of magnitude of the size of such molecules with ordinary laboratory equipment.

A mole of a molecular substance is the quantity of the substance that is equal to its molecular weight expressed in grams. The number of molecules in a mole of a molecular substance is an important physical constant known as the Avogadro number. Its value is 6.0219×10^{23} molecules per mole. In this experiment we shall also attempt to verify the Avogadro number.

OBJECTIVE

After completing this experiment, you should understand how the number of molecules in one mole of a molecular substance can be determined.

APPARATUS

ripple tank, or other large dish about 60 cm square
meterstick
saltshaker
1-mL pipet
10-mL graduated cylinder
oleic acid in alcohol solution, 1:500
lycopodium powder, or fine talcum powder
concentrated hydrochloric acid

PROCEDURE

Pour water into a ripple tank to a depth of about one centimeter, and with the use of a saltshaker, dust the water surface very lightly with lycopodium powder or talcum powder. Using a 1-mL pipet, place one drop of oleic acid solution on the water surface. The oleic acid pushes the powder outward so that the area of the oleic acid layer is visible.

Figure 15-1 shows the tank before and after the drop of oleic acid solution is placed in it. The oleic acid layer should be roughly circular in shape. If it is not, repeat the experiment until the layer is circular. Measure the diameter of the layer and record it in the data table.

Repeat the experiment, but this time add 20 mL of concentrated hydrochloric acid to the water before dusting it with lycopodium or talcum. Measure the diameter of the oleic acid layer as before and record.

The diameter of the oleic acid layer will be considerably larger in the acid solution than it is in plain water. This indicates that the oleic acid molecule is elongated. It floats upright in water because of a slight attraction between one end of the oleic acid molecule and water. Hydrochloric acid destroys this attraction, however, and in the acid solution the oleic acid molecule floats on its side. Hence, a cylinder is a good approximation of the shape of the molecule.

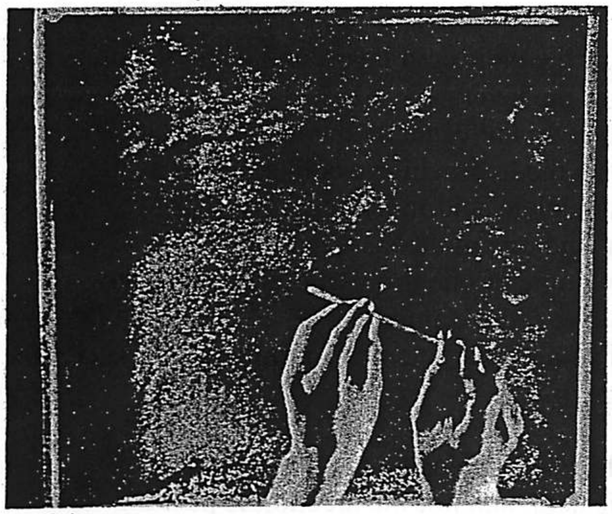

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Figure 15-1 A

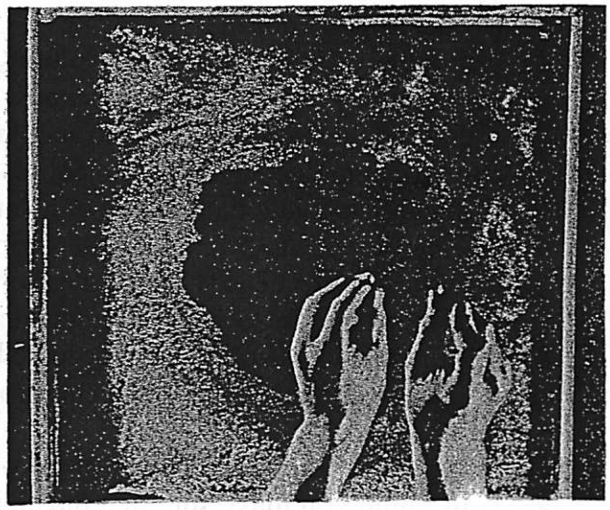

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Figure 15-1 B

Fill the pipet to the 1.0-mL mark with oleic acid solution and count the number of drops as you let the solution drain slowly from the pipet. Record this number in the data table as the number of drops of oleic acid solution in a cubic centimeter.

DATA AND CALCULATIONS TABLES

DATA TABLE

TRIAL	*Diameter of layer* (cm)	*Drops of solution* (cm^{-3})
1		
2		

Samples

CALCULATIONS TABLE

TRIAL	1	2
Area of layer	cm^2	cm^2
Volume of one drop of oleic acid solution	cm^3	cm^3
Volume of oleic acid in one drop of solution	cm^3	cm^3
Thickness of layer	cm	cm
Volume of oleic acid molecule	cm^3	
Volume of one mole of oleic acid	cm^3	
Avogadro number, experimental		
Avogadro number, accepted		
Absolute error		
Relative error	%	

Calculations

Show the calculations for Trial 1 in your lab notebook. Enter the results of the calculations for both trials in your data tables.

1. Calculate the area of the oleic acid layer from its measured diameter.
2. From the number of drops of oleic acid solution per cubic centimeter, calculate the volume of one drop of the solution.
3. Using the dilution ratio of the solution, 1:500, calculate the volume of oleic acid in one drop of solution.
4. Using the volume in #3 so the volume of the oleic acid layer, and using the area of the layer in #1, calculate the thickness of the layer.
5. Using the thickness of the oleic acid layer on the water as the height of the cylindrical molecule and the thickness on the hydrochloric acid solution as the diameter, calculate the volume of a single oleic acid molecule.
6. The density of oleic acid is 0.985 g/cm^3 and one mole has a mass of 282 g. Using the equation for density, calculate the volume of one mole of oleic acid.
7. From the answers to 5 and 6, calculate Avogadro's number.
8. Compare your result with the accepted value for Avogadro's number and calculate the absolute and percent errors.

Questions

1. What is the ratio of the height of the oleic acid molecule to its diameter?
2. How could you make sure that the oleic acid, and not the alcohol, is pushing the powder aside?
3. What properties of oleic acid make it desirable for this experiement?
4. How does the surface tension of water help this experiment? How does it hinder the experiment?